Microphonics considerations on the generator forward power

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This is a short note to summarize the equations used in the Q_L optimization for microphonics.

Input Parameters:

RF parameters

RF frequency: $\omega_{RF} = 2\pi f_{RF}$

Cavity parameters

Cavity accelerating voltage: V_{cav}

Cavity unloaded quality factor: Q_0

Cavity normalized shunt impendance: R/Q

Beam parameters

Beam DC current: I_b

Beam accelerating phase angle: Φ_b in deg.

Microphonics parameters

Detuning: δf in Hz

Intermediate values:

Following are intermediate parameters used in the optimization calculations. Some definitions are also given below.

Power lost in the cavity walls:

$$P_{\text{diss}} = \frac{V_{\text{cav}}^2}{R_{\text{sh}}} \tag{1}$$

where $R_{\text{sh}} = \frac{R}{Q} \times Q_0$ is the cavity shunt impedance.

Ratio of power delivered to the beam to that lost in the cavity walls:

$$b = \frac{P_{\text{beam}}}{P_{\text{diss}}} \tag{2}$$

Cavity unloaded bandwidth:

$$\Delta f_0 = \frac{f_0}{Q_0} \tag{3}$$

Static cavity detuning, optimized for no reflected power: [1]

$$\delta f_0 = -\frac{f_0}{2}\left(\frac{R}{Q}\right)\frac{I_b}{V_{\text{cav}}}\sin\Phi_b \tag{4}$$

Optimal loaded Q for minimal generator power including microphonics:

Optimal coupling coeffient: [1]

$$\beta_0 = \sqrt{(b+1)^2 + (2\frac{\delta f + \delta f_0}{\Delta f_0} + b\tan\Phi_b)^2} \tag{5}$$

where δf is the detuning due to microphonics, δf_0 is the cavity static detuning optimized for zero reflected power and Δf_0 is the unloaded cavity bandwidth.

Optimal coupling:

$$Q_{L_0} = \frac{Q_0}{1+\beta_0} \tag{6}$$

Forward generator power, for optimal loaded quality factor Q_{L_0} and optimal static detuning δf_0: [1]

$$P_{\text{gen}} = \frac{V_{\text{cav}}^2}{R_{\text{sh}}}\frac{1}{4\beta_0}\left[(1+b+\beta_0)^2 + (2\frac{\delta f + \delta f_0}{\Delta f_0} + b\tan\Phi_b)^2\right] \tag{7}$$

where δf is the detuning due to microphonics, δf_0 is the cavity static detuning optimized for zero reflected power and Δf_0 is the unloaded cavity bandwidth.

References

[1] Lia Merminga, Jean Delayen, "On the optimization of Q_{ext} under heavy beam loading and in the presence of microphonics", CEBAF TN-96-022, May 1996.